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Experimental Study on Overflow Pipe Structure of the Rod Pump with Down-hole Oil-water Hydrocyclone

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Abstract

For the problem of high water cut oil producing well, the technology that the oil-water is separated and injected to down hole can reduce cost price. The down-hole oil-water separation system is composed of double fluid flow pump, oil-water hydrocyclone and oil lift pump. This system runs well on site. Experimental study finds that the hydrocyclone which has cylinder-cone-inverted cone overflow pipe can reduce the short-circuit flow, and that the average separation efficiency of the hydrocyclone can reach 98.1%, and that the average reduction rate of separation efficiency is 0.51% in intermittent flow, and it decreases slowly with the ratio of split ratio divided by oil content increasing.

Keywords: down-hole oil-water separation; hydrocyclone; separation efficiency

1. Introduction

Recently, the most oil fields in China have been entering into the middle and high water cut stage of development, and the water cut rates of part of the oil fields have been more than 90%, so it is particularly important to reduce the equipment investment, the costs of operation and maintenance, and relieve the environmental pressure caused by water leaks and emissions [1-2]. By using the down-hole oil-water hydrocyclone and injection technology, we can extract and inject most of the water of the high water

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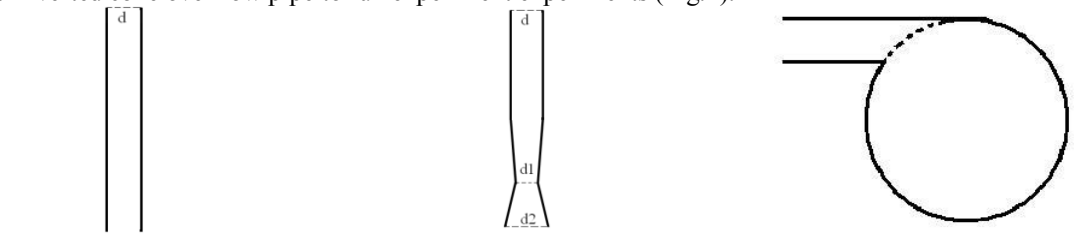
content crude oil at the bottom of the same well, and reduce oil production costs.

The down-hole oil-water separation system is composed of double fluid flow pump, oil-water hydrocyclone and oil lift pump. Due to space constraints underground, the separation efficiency of hydrocyclone determines the use effect of the entire system, and separation efficiency of hydrocyclone is determined by the structure of hydrocyclone and rotation strength of its internal flow [3]. The hydrocyclone overflow pipe structure has a great effect on short-circuit flows and separation performance [4]. Based on the numerical simulation of flow field of hydrocyclone, we design a hydrocyclone which has cylinder-cone-inverted cone overflow pipe, and have laboratory experiment.

2. Influence of overflow pipe structure on separation efficiency of hydrocyclone in continuous flow

The main structure of the hydrocyclone with rectangular tangential inlet in experiment is the same in size. And we use the hydrocyclone with cylinder type overflow pipe and the hydrocyclone with cylinder-cone-inverted cone overflow pipe to run experiment experiments (Fig.1).



cylinder type overflow pipe cylinder-cone-inverted cone overflow pipe inlet

Fig.1 The structure of entrance and overflow pipe (d=6mm, d_1=5.5mm, d_2=7mm)

2.1. Experimental facilities and process

⑴Experiment facilities

Hydrocyclone(the main diameter is 30mm, the angle of large taper is 20°, angle of small taper is 1.5°, the diameter of cylindrical is 60mm, the diameter of under flow pipe is 15mm); 50D8×5 centrifugal pump; DE-HSUL28 water in oil analyzer; LWGY-25 turbo flow meter; 723 ultraviolet spectrophotometer.

(2) Physical property of crude oil

Density: 902 kg s/m^3 (50℃)

Viscosity: 15.2 mPa·s (50℃, 1atm)

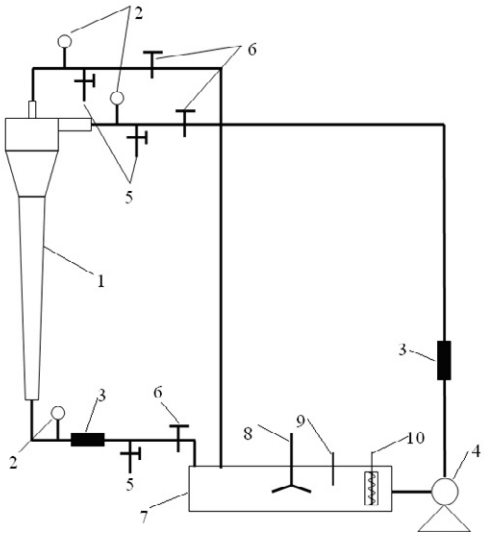
(3) Flow chart of experimental processing

Fig.2 depicts the flow chart of experimental processing. Mix crude oil and water with a certain proportion in circulating water tank, and heat to 50℃, and then separate the mixture with hydrocyclone. In the process of separating them, very low oil cut water pass the under flow pipe to enter into the circulating water tank, and low water cut oil pass the overflow pipe to enter into the circulating water tank, and the liquid mixes again. Install sample points at the inlet pipe, overflow pipe, and underflow pipe to take samples at any time.

When we do experiments, connect pipes, open all valves, run centrifugal pump, adjust the flow rate of inlet to about 4.5m^3/s, and adjust the split ratio to about 35%. After the liquid flows steadily, record the pressure, flow rate, take sample and calculate split ratio and separation efficiency.

(4) Data gathering

The oil concentration of inlet and overflow is measured by water in oil analyzer, and that of underflow is measured by ultraviolet spectrophotometer.



1-hydrocyclone, 2-pressure gauge, 3-turbo flow meter, 4-centrifugal pump, 5-sample point, 6-valve, 7-circulating water tank, 8-agitator, 9-thermometer, 10-heating pipe
Fig.2 The flow chart of experimental in continuous flow

2.2. Experimental data analysis

Record experimental data once every 5 minutes under the same experimental condition, and calculate the average value per five recorded data. Experimental result shows as fig.3.

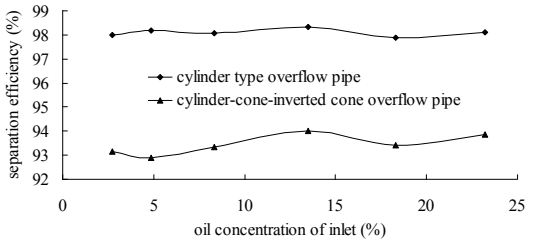


Fig.3 Influence of overflow pipe structure on separation efficiency of hydrocyclone in continuous flow

Fig.3 shows that the average separation efficiency of hydrocyclone with cylinder type overflow pipe is 93.5%, and the separate efficiency has major fluctuation when the oil concentration of inlet varies. There are two reasons. First, because of being limited by the space underground，hydrocyclone has to be made with single inlet port. This makes the centre of swirl generated by the liquid flowing into hydrocyclone deviate axial line of hydrocyclone. At the same time, the separated oil under the influence of the centrifugal force also deviate axial line of hydrocyclone. As a result, the separated oil can not go through the overflow pipe very well. Second, this structure of hydrocyclone can generate short-circuit flow easily.

The average separation efficiency of hydrocyclone with cylinder-cone-inverted cone overflow pipe is 98.1%, and the separate efficiency has slight fluctuation when the oil concentration of inlet varies. The reasons are as follow:

On one hand, because of the diameter of the bottom of this overflow pipe being bigger than that of the cylinder type overflow pipe, although the separated oil under the influence of the centrifugal force deviate axial line of hydrocyclone, it can go through the overflow pipe well. On the other hand, the hydrocyclone with cylinder-cone-inverted cone overflow pipe can destroy the growth of boundary layer, and effectively

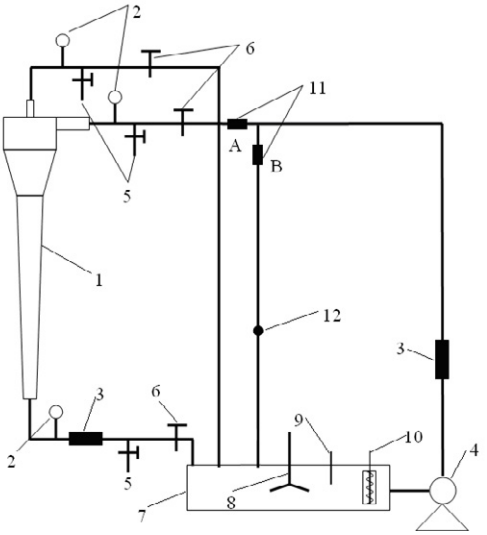
prevent the generation of short-circuit flow.

3. Influence of overflow pipe structure on separation efficiency of hydrocyclone in intermittent flow

The down-hole oil-water separation system whose motive force is provided by a beam pumper on the ground with rod is composed of double fluid flow pump, oil-water hydrocyclone and oil lift pump.

On the upstroke, the high water content crude oil is separated by hydrocyclone. And on down stroke, there is no fluid entering into the hydrocyclone. So the crude oil flow in hydrocyclone is intermittent flow.

In order to research the influence of intermittent flow on separation efficiency, install ZCS-25 electron magnetic valves and back pressure control valve on the pipes (Fig.4). The electron magnetic valves up/down 4 times every minute (The situation of valve A and that of valve B are opposite.).



1-hydrocyclone, 2-pressure gauge, 3-turbo flow meter, 4-centrifugal pump, 5-sample point, 6-valve, 7-circulating water tank, 8-agitator, 9-thermometer, 10-heating pipe, 11-electron magnetic valve, 12-back pressure control valve

Fig.4 The flow chart of experimental in intermittent flow

Table 1 the experimental data

Entrance Type	Flow rate of inlet (m^3/h)	Split ratio (%)	Oil concentration			Separation efficiency of Continuous flow (%)	Separation efficiency of Intermittent flow (%)	Decline rate of separation efficiency (%)
			Inlet (%)	Underflow (continuous flow)(mg/L)	Underflow (intermittent flow)(mg/L)			
Conventional cylinder type overflow pipe	4.2	35.71	3.1	2011.9	2293.1	93.51	92.6	0.97
	4.7	34.04	4.9	3160.5	3641.8	93.55	92.57	1.05
	4	35	6.1	3958.9	4626.3	93.51	92.42	1.17
	4.5	33.33	8.5	5567.5	6568.3	93.45	92.27	1.26
	4.8	35.42	10.3	6725.9	7756	93.47	92.47	1.07
cylinder-cone-inverted cone overflow pipe	4.5	35.56	2.9	545.2	681.8	98.12	97.65	0.48
	4.7	38.3	4.5	904.5	1129.4	97.99	97.49	0.51
	4.6	34.78	6.7	1299.8	1648	98.06	97.54	0.53
	4.2	33.33	8.3	1552.1	2024.5	98.13	97.56	0.58
	4.6	36.96	9.9	1831.5	2268.8	98.15	97.71	0.45

When we do experiments, first, open all valves except valves B, run centrifugal pump, adjust the flow

rate of inlet to about 4.5m^3/s, adjust the split ratio to about 35%. After the liquid flows steadily, record the pressure, flow rate, take sample and calculate split ratio and separation efficiency. Second, switch electron magnetic valves periodical. After the liquid flows steadily, record the pressure, flow rate, take sample and calculate split ratio and separation efficiency. The experimental data is in table 1.

Table 1 show that the separation efficiency of intermittent flow is lower than that of continuous flow. The average rate of decline of hydrocyclone with cylinder type overflow pipe is 1.1%, and the average rate of decline of hydrocyclone with cylinder-cone-inverted cone overflow pipe is 0.51%.

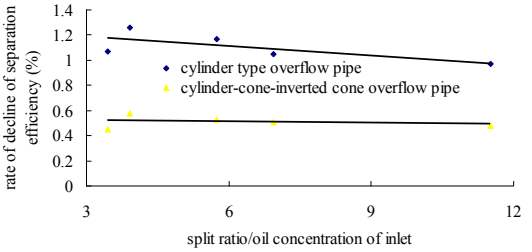


Fig.5 the rate of decline of separation efficiency

Fig.5 shows that the rate of decline of separation efficiency is decreasing with the ratio of split ratio divided by oil content increasing. The decline trend of hydrocyclone with cylinder-cone-inverted cone overflow pipe is slower than that of hydrocyclone with cylinder type overflow pipe.

4. Conclusion

(1) The average separation efficiency of hydrocyclone with cylinder-cone-inverted cone overflow pipe is 98.1%, and the separate efficiency has slight fluctuation when the oil concentration of inlet varies.

(2) The average rate of decline of hydrocyclone with cylinder-cone-inverted cone overflow pipe is 0.51%, and the decline trend of this hydrocyclone is very slow with the ratio of split ratio divided by oil content increasing.

(3) The hydrocyclone with cylinder-cone-inverted cone overflow pipe can effectively prevent the generation of short-circuit flow, and enhance the separate efficiency.

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